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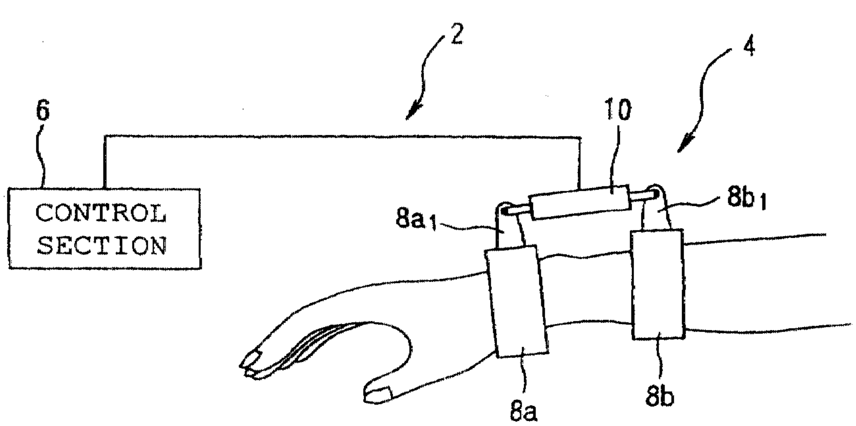
(54) **Wearable muscular-force supplementing device**

(57) A muscular-force supplementing device (2) of the present invention includes an artificial muscular-force generating section (4) and a control section (6) for controlling the driving of the artificial muscular-force generating section (4). The artificial muscular-force generating section (4) is composed of a pair of mounting portions (8a) and (8b) worn at two positions on both sides of a wrist joint of the user, and an actuator (10) hinged on connecting portions (8a1) and (8b1) of the mounting portions (8a) and (8b). The actuator (10) is a device having therein a plurality of hydraulic cylinders to be operated in a dual-stroke manner. When hydraulic oil serving as the fluid is supplied to pressure chambers, a pair of piston rods are extended, and linear actuator force is transmitted to the connecting portions (8a1) and (8b1) of the mounting portions (8a) and (8b), thereby transmitting bending force to the joint of the user.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a wearable muscular-force supplementing device to be worn at joints of the wrist, arm, knee, and the like of a user so as to generate supplementary muscular force.

Background Art

[0002] As conventional wearable muscular-force supplementing devices, techniques are disclosed in, for example, Japanese Unexamined Patent Application Publication No. 7-163607 (hereinafter referred to as a "first conventional art") and Japanese Unexamined Utility Model Application Publication No. 5-39518 (hereinafter referred to as a "second conventional art").

[0003] The first conventional art comprises a thigh-worn portion to be worn on the thigh of a user, a shank-worn portion to be worn on the shank, power transmission arms fixed to the thigh-worn portion and the shank-worn portion at one end and connected to each other at the other end at a knee joint so as to bend and straighten the joint, a driving section using an electromotor for applying power for bending and straightening to the power transmission arms, and a power-source and control section for the electromotor and driving section. The power-source and control section is worn on the body of the user. In the driving section, a joint shaft connected to the power transmission arms rotates together with one of the power transmission arms. A gear mounted on an output shaft of the electromotor is meshed with a gear mounted on the joint shaft, and power transmission is enabled and disenabled between the gear of the joint shaft and the joint shaft via a clutch.

[0004] The first conventional art makes it possible to assist persons having low muscular strength in the legs, persons of advanced age, and the like in the climbing of stairs.

[0005] The second conventional art comprises a shoulder-fixed member to be supported on the front side of the shoulder of a disabled arm, and an upper-arm-fixed member and a forearm-fixed member, respectively supported on the upper arm and the forearm. The upper-arm-fixed member and the forearm-fixed member are connected at the elbow, and an artificial rubber muscle is extended between the shoulder-fixed member and the forearm-fixed member so as to be expanded and contracted in response to changes in the internal air pressure thereof.

[0006] According to the second conventional art, a special electronic circuit (controller) and the like are unnecessary, and the range of movement can be easily set by utilizing the spring characteristics of the artificial rubber muscle in accordance with air pressure and contraction efficiency corresponding thereto.

[0007] However, the first conventional art has the following problems:

(1) While power transmission is enabled and disenabled by the clutch, for example, when a user climbing the stairs is going to fall down while power is being transmitted, the clutch cannot be quickly disengaged. In this case, even if the user, who is going to fall down, desires to quickly assume a recovery attitude, the user cannot freely move the legs and may be placed into a dangerous situation because the clutch is engaged.

(2) Since supplementary muscular force is automatically generated in response to a specific attitude of the user, the user cannot do anything else except remove the device when supplementary muscular force is unnecessary.

(3) In order to change the power of the supplementary muscular force as the user desires, it is necessary to change the output of the electromotor in the driving section. For this reason, a high-output electromotor must be used to respond to increases and decreases in the power of supplementary muscular force. This increases the size of the device.

(4) A heavy power source must be worn on the body of the user, and this may limit the motion of the user. While a myoelectric sensor is used to check the muscular force of the user, mounting of the myoelectric sensor is troublesome, and inflammation of the skin is sometimes caused due to adhesive tape or the like used to hold the sensor on the skin.

(5) For example, when the device is worn on the body in winter, cold instruments are in contact with the skin, and the user feels cold and uncomfortable.

[0008] The second conventional art has the following problems:

(6) Even when the user, who is going to fall down, desires to quickly assume a recovery attitude, he or she cannot support the entirety of the body because the arm is restrained. This may lead to a dangerous situation.

(7) Since the artificial rubber muscle has only a single pressure chamber, when the pressure chamber is ruptured, supplementary muscular force is suddenly lost. In a case in which supplementary muscular force is suddenly lost while the user is carrying something heavy, the body of the user may be injured.

(8) Artificial rubber muscles may be arranged in parallel in order to increase the power of supplementary muscular force. When a plurality of artificial rub-

ber muscles are thus arranged, the number of external tubes to be connected thereto is increased, and therefore, it is troublesome to handle the external tubes so that they do not become entangled.

(9) The artificial rubber muscle is stiffened and contracted by pressure, thereby bending the arm of the user. Since the contracted artificial rubber muscle lies in the bending direction of the arm of the user, however, it reduces the range of movement of the arm of the user.

(10) Since the artificial rubber muscle serving as an actuator is not in close contact with the body, problems occur; for example, a portion of clothing (a shirt or a coat) becomes entangled therein. Furthermore, when the user wears the device over a shirt, he or she cannot wear a jacket thereover.

(11) In a manner similar to that in the first conventional art, when the device is worn on the body in winter, the user feels cold and uncomfortable.

[0009] An object of the present invention is to provide a wearable muscular-force supplementing device which is easily handled with a fail-safe mechanism for the body of a user, for example, which immediately stops generation of supplementary muscular force in the case of an emergency and prevents generated force from being suddenly reduced even when an actuator breaks, which is easily wearable with the actuator not protruding from a joint of the user, which is so compact as not to reduce the range of movement of the joint of the user, which is so light in weight that it does not restrain the movement of the user, and which does not cause the user to feel uncomfortable, such as feel cold, when wearing the device.

Disclosure of Invention

[0010] A wearable muscular-force supplementing device according to an aspect of the present invention includes an artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user, and a control means for controlling the driving of the artificial muscular-force generating means, wherein the control means has an artificial muscular-force releasing means for releasing the joint from restraint by stopping generation of supplementary muscular force by the artificial muscular-force generating means.

[0011] According to this invention, when the user assumes a dangerous attitude, for example, when the user is going to fall down, generation of supplementary muscular force in the artificial muscular-force generating means is stopped, and therefore, the user can freely move the body without any restraint from the artificial muscular-force generating means.

[0012] Preferably, the artificial muscular-force releasing means has a sensor means for detecting the attitude of the user, and a release control means for stopping generation of supplementary muscular force by the artificial muscular-force generating means when determining, based on information detected by the sensor means, that the user is in a dangerous attitude, for example, indicating that the user is going to fall down.

[0013] In this case, the sensor means detects a dangerous position, for example, a state in which the user is going to fall down. The release control means can stop generation of supplementary muscular force by the artificial muscular-force generating means based on information detected by the sensor means.

[0014] The control means may have a voice input means, and may control generation of supplementary muscular force to be applied to the joint by the artificial muscular-force generating means or may exert control so as to operate the artificial muscular-force releasing means, based on voice input from the voice input means.

[0015] In this case, supplementary muscular force is generated in the artificial muscular-force generating means when the user says "Start", and the generation of supplementary muscular force by the artificial muscular-force generating means is stopped when the user says "Stop". When the user says "Danger", the artificial muscular-force releasing means is operated to release the joint from restraint.

[0016] The artificial muscular-force generating means may have a fluid-pressure type actuator, and the control means may include a reservoir for storing fluid, a fluid feeding device for pressurizing and transferring the fluid received from the reservoir to the actuator, and a feeding-drive control device for controlling the fluid feeding device. The artificial muscular-force releasing means may have a control valve interposed in a fluid path communicating with the actuator and connected to the reservoir while detouring around the fluid feeding device, and the release control means may have an opening control section for controlling the opening of the control valve.

[0017] In this case, when the release control means detects, from an acceleration sensor, a dangerous attitude of the user, for example, a state in which the user is going to fall down, it exerts control so as to open the control valve. Thereby, the fluid in the actuator is fed back to the reservoir, and generation of supplementary muscular force by the artificial muscular-force generating means can be stopped.

[0018] A wearable muscular-force supplementing device according to another aspect of the present invention includes an artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user, and a control means for controlling the driving of the artificial muscular-force generating means, wherein the control means has a generated-force stabilizing means for inhibiting force generated

by the artificial muscular-force generating means from being reduced due to breakage.

[0019] In this case, even when an actuator breaks while the user is carrying something heavy, the generated-force stabilizing means prevents force generated by the actuator from being suddenly reduced. Therefore, the body of the user will not be injured.

[0020] The artificial muscular-force generating means may include a fluid-pressure type actuator having a plurality of pressure chambers, and the generated-force stabilizing means may separate the pressure chambers.

[0021] In this case, even when the actuator is partly broken, since the generated-force stabilizing means separates the broken pressure chamber, generated force of the actuator can be prevented from being suddenly reduced.

[0022] The control means may include a reservoir for storing fluid, a fluid feeding device for pressurizing and transferring the fluid received from the reservoir to the actuator, and a feeding-drive control device for controlling the fluid feeding device. The generated-force stabilizing means may include a pressure sensor for detecting the pressures in the pressure chambers, control valves interposed in a plurality of flow paths connected between the fluid feeding device and the pressure chambers of the actuator, and a generated-force stabilization control section for closing a control valve connected to a given pressure chamber when it is determined based on information detected by the pressure sensor that the pressure in the pressure chamber has decreased.

[0023] In this case, the pressure sensor detects that a given pressure chamber of the actuator is in an abnormal condition. The generated-force stabilization control section closes a control valve connected to the given pressure chamber. Since the broken pressure chamber is thereby separated, the force generated by the actuator will not be suddenly reduced.

[0024] A wearable muscular-force supplementing device according to a further aspect of the present invention includes an artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user, and a control means for controlling the driving of the artificial muscular-force generating means, wherein the artificial muscular-force generating means is electrically driven, there are two power sources, a main power source and an auxiliary power source, the main power source and the auxiliary power source are connected to a power switching device, and the power switching device performs switching so as to supply power from the auxiliary power source for a predetermined time when power supply from the main power source is stopped.

[0025] In this case, since power is supplied from the auxiliary power source when supply from the main power source is stopped, it is possible to avoid the danger of a sudden stop of generation of supplementary muscular force.

[0026] The power switching device may have an alarm device for sounding an alarm when power supply from the auxiliary power source is started.

[0027] This makes it possible to reliably inform the user that power supply from the main power source has stopped.

[0028] A wearable muscular-force supplementing device according to a further aspect of the present invention includes an artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user, and a control means for controlling the driving of the artificial muscular-force generating means, wherein the artificial muscular-force generating means has a pair of mounting portions to be worn at two positions on the body of the user on both sides of the joint, and an actuator connected between the mounting portions, and the actuator has a restraint means for preventing excessive supplementary muscular force from being applied to the joint of the user.

[0029] In this case, the joint will not be damaged by excessive supplementary muscular force. As the restraint means, the mounting portions may be provided with stopper members placed opposed to each other so that the positions thereof are adjustable and so that the stopper members contact before excessive supplementary muscular force is applied to the joint of the user. As the restraint means, a variable-length elastic belt may be connected between the mounting portions so that the force of the actuator is stopped by tension generated by the elastic belt before excessive supplementary muscular force is applied to the joint of the user.

[0030] This makes it possible to prevent, by a mechanical structure, the joint from bending excessively.

[0031] A wearable muscular-force supplementing device according to a further aspect of the present invention includes an artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user, and a control means for controlling the driving of the artificial muscular-force generating means, wherein the artificial muscular-force generating means has a pair of mounting portions to be worn at two positions on the body of the user on both sides of the joint, and an actuator connected between the mounting portions, the actuator is composed of a plurality of actuator divisions arranged in parallel and connected to one another between the mounting portions, the mounting portions have connecting portions for detachably connecting the actuator divisions thereto, and a predetermined number of actuator divisions are detachably connected to the connecting portions of the mounting portions in accordance with a desired power of supplementary muscular force.

[0032] In this case, since actuator force can be changed only by connecting a predetermined number of actuator divisions to the connecting portions of the first and second mounting portions, it is possible to freely set the power of supplementary muscular force as the user desires. By detaching the actuator divisions de-

tachably connected to the connecting portions of the first and second mounting portions, the artificial muscular-force generating means can be made compact.

[0033] The actuator divisions may be formed of fluid-pressure type actuators each having a pressure chamber therein, and the connecting portions of the mounting portions may also serve as fluid transfer connectors for transferring fluid serving as working fluid into and out of the pressure chambers of the actuator divisions.

[0034] In this case, the tubes and the like for supplying fluid are not exposed outside the device, and the artificial muscular-force generating means can be handled easily.

[0035] A wearable muscular-force supplementing device according to a further aspect of the present invention includes an artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user, and a control means for controlling the driving of the artificial muscular-force generating means, wherein the artificial muscular-force generating means has an actuator serving as a fluid chamber having a pressure chamber, and the control means includes a fluid transfer control section for controlling transfer of the fluid with respect to the actuator, and at least one of the actuator and the fluid transfer control section has a fluid discharge control section for discharging internal fluid to the outside.

[0036] In this case, when the fluid is a liquid, such as hydraulic oil, the weight of the device is reduced by discharging at least one of the fluid in the actuator and the fluid in the fluid transfer control section to the outside by the fluid discharge control section. This facilitates an operation of transporting the device in a non-operation state.

[0037] The fluid discharge control section may have a leakage alarm means for detecting leakage of the fluid and sounding an alarm when discharge of the fluid out of at least the actuator and the fluid transfer control section is stopped.

[0038] This makes it possible to allow the user to immediately ascertain that an abnormal condition exists in which fluid is leaking to the outside.

[0039] The control means may include a fluid supply control section capable of supplying the fluid from the outside to at least one of the actuator and the fluid transfer control section, and a filter means placed at an inlet of the fluid supply control section so as to remove foreign matters mixed in the fluid. In this case, the filter means removes impurities, such as dust, mixed in the fluid. For this reason, since the fluid transfer control section feeds and feeds back the fluid having no impurities, it is possible to substantially reduce problems resulting from impurities.

[0040] A wearable muscular-force supplementing device according to a further aspect of the present invention includes an artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user, and a control means for controlling the driving of the artificial muscular-force generating means, wherein the control means is driven by power from an external power source, and has a power cord to be connected to the external power source, and a cord reel for winding up the power cord thereon.

[0041] In this case, when the power cord is drawn out of the cord reel only by a required length, it is prevented from becoming entangled.

[0042] The cord reel may be worn on the body of the user via a holder, and the holder may have a mechanism for allowing a cord-dispensing hole of the cord reel to freely point upward, downward, rightward, and leftward.

[0043] Since the cord-dispensing hole of the cord reel is thereby controlled so as to constantly point in the extending direction of the power cord (toward a socket), the power cord can be smoothly drawn out of the cord reel.

[0044] The control means may have a power cord alarm means for sounding an alarm when it is determined that only a short length of power cord remains in the cord reel.

[0045] In this case, it is possible to avoid a dangerous operation, in which for example, the power cord is forcibly disconnected from a socket due to a great pulling force applied to a plug because only a short length of power cord remains in the cord reel.

[0046] A wearable muscular-force supplementing device according to a further aspect of the present invention includes an artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user, and a control means for controlling the driving of the artificial muscular-force generating means, wherein the artificial muscular-force generating means has a flexible mounting portion shaped like a cylinder so as to wrap the joint of the user in close contact therewith, and a fluid-pressure type actuator formed integrally with the outer periphery of the mounting portion so as to apply supplementary muscular force to the joint while bending the mounting portion.

[0047] In this case, since no member protrudes from the mounting portion, the user can easily wear clothing with the device worn on the body.

[0048] The control means may have a heating device for heating fluid serving as working fluid for the actuator to a predetermined temperature.

[0049] In this case, when the fluid heated by the heating device flows into the actuator, the temperature of the mounting portion formed integrally with the actuator rises.

[0050] The mounting portion may be provided with a muscular force detecting means for measuring muscular force based on pressing force temporarily applied to the skin of the user, and the control means may control supplementary muscular force generated by the actuator based on muscular force information obtained from the muscular force detecting means. The muscular force detecting means may include a driving motor, a transmission mechanism for transmitting rotating force

of the driving motor as linear motion to a pushrod, and a torque measuring instrument for measuring the torque value of the driving motor when the skin is pushed by the pushrod and outputting the torque value as the pressing force to the control means.

[0051] Since this eliminates the necessity of placing the device into contact with the skin, as in a myoelectric sensor or the like, it is possible to reduce the time for measuring the muscular force and to prevent inflammation of the skin.

[0052] The actuator may be composed of an inner actuator placed on the inner side of the joint, extending in the longitudinal direction of the outer periphery of the mounting portion, and having a pressure chamber made of an elastic material, and an outer actuator placed on the outer side of the joint, extending in the longitudinal direction of the outer periphery of the mounting portion, and having a pressure chamber made of an elastic material. The inner and outer actuators may each have a plurality of convex members fixed on the outer periphery of the mounting portion with a predetermined space therebetween in the longitudinal direction, and a plurality of elastic members placed in the spaces between the convex members. Each of the elastic members may be expanded and contracted in response to the inflow and outflow of fluid into and from the pressure chamber formed therein, and each of the convex members may be pressed by expansion of the elastic member so as to apply bending force to the mounting portion.

[0053] In this case, when the fluid flows into the pressure chambers of the elastic members of the inner actuator, bending force acts on the mounting portion and supplementary muscular force is applied so as to bend the joint of the user. When the fluid flows into the pressure chambers of the elastic members of the outer actuator, bending force to the mounting portion is released and supplementary muscular force can be applied so as to straighten the joint of the user.

[0054] The control means may exert control so as to transfer fluid between the pressure chambers of the elastic members constituting the inner actuator and the pressure chambers of the elastic members constituting the outer actuator.

[0055] In this case, the pressure chambers in the outer actuator also serve as reservoirs when putting fluid into the pressure chambers of the inner actuator, and the pressure chambers in the inner actuator also serve as reservoirs when putting fluid into the pressure chambers of the outer actuator. Therefore, no reservoirs are necessary, or only a reservoir having a small capacity is necessary so as to supplement leakage of a small amount of working fluid. This reduces the amount of working fluid and allows a smaller and lighter device.

[0056] The actuator may be composed of an outer actuator placed on the outer side of the joint, extending in the longitudinal direction of the outer periphery of the mounting portion, and having a pressure chamber made of an elastic material, and the outer actuator may be expanded in the longitudinal direction in response to the inflow of the fluid into the pressure chamber so as to apply bending force to the mounting portion, and may be contracted in response to the outflow of the fluid from the pressure chamber so as to release the bending force on the mounting portion. The outer actuator may include a plurality of convex members fixed on the outer periphery of the mounting portion with a predetermined space therebetween in the longitudinal direction, and a plurality of elastic members placed in the spaces between the convex members. The elastic members may be expanded in the longitudinal direction in response to the inflow of the fluid in the pressure chamber formed therein so as to press the convex members and to apply bending force to the mounting portion.

[0057] In this case, when the outer actuator is expanded so as to apply bending force to the mounting portion, supplementary muscular force is applied to bend the joint of the user. When the outer actuator is contracted so as to release the bending force on the mounting portion, supplementary muscular force is applied to straighten the joint of the user. Since the outer actuator, which is hardened by pressure, is placed on the outer side of the joint, it does not hinder bending of the arm of the user and does not reduce the range of movement of the arm.

[0058] The control means may have a generated-force stabilizing means for inhibiting the force generated by the artificial muscular-force generating means from being reduced due to breakage.

[0059] In this case, even when the artificial muscular-force generating means breaks while the user is carrying something heavy, the generated-force stabilizing means prevents the force generated by the artificial muscular-force generating means from being suddenly reduced. Therefore, the body of the user will not be injured.

[0060] The convex members may function as stopper members for stopping application of supplementary muscular force by contacting with one another before excessive supplementary muscular force is applied to the joint of the user.

[0061] This makes it possible to prevent, by the mechanical structure, the joint from bending excessively.

[0062] Furthermore, the fluid may be liquid, and the outer periphery of the mounting portion may be coated with a periphery-coating member having a liquid absorbing function.

Brief Description of the Drawings

[0063]

Fig. 1 is a view of a wearable muscular-force supplementing device according to a first embodiment of the present invention.

Fig. 2 is a view showing the structure of an actuator

for constituting an artificial muscular-force generating means in the wearable muscular-force supplementing device of the first embodiment.

Fig. 3 is a block diagram showing the details of a control section in the wearable muscular-force supplementing device of the first embodiment.

Fig. 4 is a view of a wearable muscular-force supplementing device according to a second embodiment.

Fig. 5 is a view of a wearable muscular-force supplementing device according to a third embodiment.

Fig. 6 is a view of a wearable muscular-force supplementing device according to a fourth embodiment.

Fig. 7 is a view of an artificial muscular-force generating means in the wearable muscular-force supplementing device of the fourth embodiment.

Fig. 8 is a view showing a state in which the artificial muscular-force generating means of the fourth embodiment is generating supplementary muscular force.

Fig. 9 is a block diagram showing the details of a control section in the wearable muscular-force supplementing device of the fourth embodiment.

Fig. 10 is a view of a cord reel for constituting the wearable muscular-force supplementing device of the fourth embodiment.

Fig. 11 is a view showing a state in which the cord reel as a component of the fourth embodiment is worn on the body of a user.

Fig. 12 is a view of a wearable muscular-force supplementing device according to a fifth embodiment of the present invention.

Fig. 13 is a view showing the structure of an actuator for constituting an artificial muscular-force generating means in the wearable muscular-force supplementing device of the fifth embodiment.

Fig. 14 is a block diagram showing the details of a control section in the wearable muscular-force supplementing device of the fifth embodiment.

Fig. 15 is a view showing the operation of the wearable muscular-force supplementing device of the fifth embodiment.

Fig. 16 is a view of a muscular-force detecting means provided in the wearable muscular-force supplementing device of the fifth embodiment.

Fig. 17 is a view of a wearable muscular-force supplementing device according to a sixth embodiment of the present invention.

Best Mode for Carrying Out the Invention

[0064] Embodiments of a wearable muscular-force supplementing device of the present invention will be described below with reference to the drawings.

[0065] Fig. 1 shows a muscular-force supplementing device 2 of a first embodiment for applying supplementary muscular force to a wrist joint of a user, which includes an artificial muscular-force generating section 4 and a control section 6 for controlling the driving of the artificial muscular-force generating section 4.

[0066] The artificial muscular-force generating section 4 comprises a pair of mounting portions 8a an 8b to be worn at two positions on both sides of a wrist joint of the user, and an actuator 10 hinged on connecting portions 8a1 and 8b1 of the mounting portions 8a and 8b.

[0067] The actuator 10 is a device having therein a plurality of hydraulic cylinders 14A, 14B, and 14C to be operated in a dual-stroke manner. As shown in Fig. 2, a plurality of cylinders 14a, 14b, and 14c are arranged in parallel in a cylindrical actuator body 12, and pistons 16a to 16f connected to the leading ends of a pair of comb-shaped piston rods 18a and 18b are slidably placed in the cylinders 14a, 14b, and 14c. When hydraulic oil serving as the fluid is supplied to pressure chambers 20a, 20b, and 20c, the piston rods 18a and 18b are extended, and linear actuator force is transmitted to the connecting portions 8a1 and 8b1 of the mounting portions 8a and 8b, thereby transmitting bending force to the joint of the user.

[0068] The outer periphery of the actuator 10 is coated with a coating material 13, such as a high polymer, which is able to absorb liquid in order to prevent the hydraulic oil from leaking to the user side.

[0069] The control section 6 comprises, as shown in Fig. 3, a reservoir 22 for storing hydraulic oil to be used in this device, a plurality of hydraulic-oil feeders 24a, 24b, and 24c for independently supplying the hydraulic oil in the reservoir 22 to the pressure chambers 20a, 20b, and 20c of the actuator 10, an artificial muscular-force releasing section 26 for releasing the force from the artificial muscular-force generating section 4 in the case of an emergency, a feeding-drive control device 28

for controlling the driving of the hydraulic-oil feeders 24a, 24b, and 24c, a power supply section 30 for supplying power to the hydraulic-oil feeders 24a, 24b, and 24c, and a generated-force stabilizing section 32 for preventing generated force of the actuator from being decreased suddenly.

[0070] The hydraulic-oil feeders 24a, 24b, and 24c are electrically driven and exert control so as to supply the hydraulic oil received from the reservoir 22 to the pressure chambers 20a, 20b, and 20c after increasing the pressure thereof to a predetermined pressure and to return the hydraulic oil.

[0071] The artificial muscular-force releasing section 26 includes a control valve 26a interposed in an oil path 25a communicating with the pressure chambers 20a, 20b, and 20c of the actuator 10 and with the reservoir 22 while detouring around the hydraulic-oil feeders 24a, 24b, and 24c, an acceleration sensor 26b for detecting the attitude of the user, and an opening control section 26c for outputting a signal for opening to the control valve 26a according to detected information obtained from the acceleration sensor 26b.

[0072] The feeding-drive control device 28 controls the operations of the hydraulic-oil feeders 24a, 24b, and 24c. This device is able to activate and deactivate the hydraulic-oil feeders 24a, 24b, and 24c through the operation of switches (not shown) and by voice input.

[0073] That is, a voice input device 34 is connected to the feeding-drive control device 28, and operation of the feeding-drive control device 28 is controlled in response to signals input from the voice input device 34. For example, when the user says "Start", the hydraulic-oil feeders 24a, 24b, and 24c are activated under control of the feeding-drive control device 28. When the user says "Stop", the hydraulic-oil feeders 24a, 24b, and 24c are deactivated. The voice input device 34 is also connected to the opening control section 26c so that the opening of the control valve 26a can be controlled by voice. For example, when the user says "Danger", the opening control section 26c outputs a signal to open the control valve 26a, so that the control valve 26a is opened.

[0074] The power supply section 30 includes two power sources, an external power source serving as a main power source and a storage battery 30a serving as an auxiliary power source. A power circuit 30b of the external power source and the storage battery 30a are connected to a power switching device 30c. When power supply from the power circuit 30b is stopped, the power switching device 30c performs switching so as to supply power from the storage battery 30a for a predetermined period. A current sensor 30d is interposed between the storage battery 30a and the power switching device 30c. When the current sensor 30d detects that the storage battery 30a is being used, an alarm device 30e sounds an alarm.

[0075] The generated-force stabilizing section 32 comprises pressure sensors 32a1, 32a2, and 32a3 for detecting the pressures in the pressure chambers 20a, 20b, and 20c of the actuator 10, control valves 32b1, 32b2, and 32b3 interposed in oil paths 25b, 25c, and 25d for supplying hydraulic oil from the hydraulic-oil feeders 24a, 24b, and 24c to the pressure chambers 20a, 20b, and 20c, and a generated-force stabilization control section 32d for obtaining pressure information from the pressure sensors 32a1, 32a2, and 32a3, and closing a control valve corresponding to a given pressure chamber in which the pressure is lower than the standard pressure (for example, the control valve 32b1 in the case of the pressure chamber 20a).

[0076] A manner of using the muscular-force supplementing device 2 with the above configuration will be described below briefly.

[0077] First, a power cord 30f of the power supply section 30 is placed into contact with a socket (not shown). Then, as shown in Fig. 1, the mounting portions 8a and 8b are put on the hand and arm sides of the user. Subsequently, the hydraulic-oil feeders 24a, 24b, and 24c are activated by operating the switches in the feeding-drive control device 28.

[0078] The hydraulic-oil feeders 24a, 24b, and 24c increase the pressure of the hydraulic oil received from the reservoir 22 to a predetermined pressure, and supply the hydraulic oil to the pressure chambers 20a, 20b, and 20c of the actuator 10, respectively. When the hydraulic oil serving as the fluid is supplied to the pressure chambers 20a, 20b, and 20c, the artificial muscular-force generating section 4 is extended in response to the supply of the hydraulic oil to the actuator 10, linear actuator force acts on the connecting portions 8a1 and 8b1 of the mounting portions 8a and 8b, and bending force (supplementary muscular force) is thereby transmitted to the joint of the user. After a predetermined time, the hydraulic-oil feeders 24a, 24b, and 24c return the hydraulic oil in the pressure chambers 20a, 20b, and 20c to the reservoir 22 so as to discontinue the transmission of the supplementary muscular force to the joint of the user.

[0079] If the user, who is walking with the muscular-force supplementing device 2 worn, is going to fall down, the acceleration sensor 26b of the artificial muscular-force releasing section 26 detects a specific acceleration value in the state in which the user is going to fall down. In this case, the opening control section 26c outputs a signal for opening to the control valve 26a based on the specific acceleration value input from the acceleration sensor 26b, thereby placing the control valve 26a into an open state. When the control valve 26a is placed in the open state, the hydraulic oil in the pressure chambers 20a, 20b, and 20c is returned to the reservoir 22 via the oil path 25a, and the actuator force of the artificial muscular-force generating section 4 is decreased to zero. In this way, when the user is going to fall down, the artificial muscular-force releasing section 26 releases the joint from restraint.

[0080] In the muscular-force supplementing device 2,

the artificial muscular-force generating section 4 can be controlled so as to start and stop generation of supplementary muscular force and the artificial muscular-force releasing section 26 is operated to release the joint from restraint, not only by operating the switches (the switches of the feeding-drive control device 28), but also by inputting voice to the voice input device 34. This makes it possible to easily respond to a demand for an emergency stop during use.

[0081] When power supply to the external power source is stopped during operation of the muscular-force supplementing device 2, the power switching device 30c performs switching so that power is supplied from the storage battery 30a. In this case, the alarm device 30e sounds an alarm so as to inform the user that the power is being supplied from the storage battery 30a.

[0082] When the power cord 30f is disconnected from the socket, the power switching device 30c also performs switching so as to supply power from the storage battery 30a, and the alarm device 30e sounds an alarm.

[0083] In a case in which trouble, such as oil leakage, occurs in any of the hydraulic cylinders constituting the actuator 10, for example, when the actuator force of the hydraulic cylinder 14A is reduced, the generated-force stabilizing section 32 exerts the following control. That is, the generated-force stabilization control section 32d ascertains, based on information from the pressure sensor 32a1, that the pressure in the pressure chamber 20a falls, and outputs a closing signal to the control valve 32b1 corresponding to the pressure chamber 20a. The faulty hydraulic cylinder 14A is thereby separated so as to prevent the force from being lost due to leakage of all the oil. The other hydraulic cylinders 14B and 14C generate the minimum required actuator force.

[0084] Therefore, in a case in which the user of the muscular-force supplementing device 2 of this embodiment is in a dangerous attitude, for example, in a case in which the user is going to fall down, the muscular-force supplementing device 2 is released by reducing the actuator force of the artificial muscular-force generating section 4 to zero under control of the artificial muscular-force releasing section 26. This allows the user to freely move the joint and to quickly assume a recovery attitude.

[0085] By inputting voice to the voice input device 34, the operation of the muscular-force supplementing device 2 can be started and stopped, and the artificial muscular-force releasing section 26 can be operated to release the joint. Therefore, the muscular-force supplementing device 2 can be used safely.

[0086] Since the power supply section 30 for supplying power to the hydraulic-oil feeders 24a, 24b, and 24c can obtain power from the storage battery 30a when the power supply from the external power source is stopped, it is possible to avoid dangers, such as a sudden loss of supplementary muscular force, and to apply supplementary muscular force until the user assumes a safe attitude.

[0087] Since the alarm device 30e sounds an alarm so as to inform the user that the power is being supplied from the storage battery 30a, it is possible to immediately ascertain the cause, for example, the disconnection of the power cord 30f from the socket.

[0088] Even when any of the hydraulic cylinders of the actuator 10 is faulty, the generated-force stabilizing section 32 exerts control so as to generate the minimum required actuator force. Therefore, it is possible to avoid dangers, for example, damage to the joint due to a sudden loss of supplementary muscular force while the user is carrying something heavy.

[0089] Since the actuator 10 of this embodiment is constituted by a plurality of hydraulic cylinders 14A, 14B, and 14C to be operated in a dual-stroke manner, it allows linear actuator force to reliably act on the connecting portions 8a1 and 8b1 of the mounting portions 8a and 8b, so that supplementary muscular force appropriate for bending can be transmitted to the joint of the user.

[0090] Fig. 4 shows a muscular-force supplementing device 40 of a second embodiment which has a structure different from that of the first embodiment shown in Figs. 1 to 3. The same components as those in the first embodiment are denoted by the same numerals, and descriptions thereof are omitted.

[0091] In this embodiment, as shown in Fig. 4(a), a pair of mounting portions 8a and 8b are provided with a pair of stopper members 42a and 42b made of a hard material and placed opposed to each other. The stopper members 42a and 42b contact at the maximum bending angle (allowable bending angle) θ which does not have any influence on a joint of the user, as shown in Fig. 4 (b), thereby inhibiting the joint from being bent at an angle greater than the allowable bending angle θ. Since the allowable bending angle θ of the joint varies among users, the distance between the stopper members 42a and 42b is adjustable.

[0092] Since the stopper members 42a and 42b prevent the joint from bending excessively, it is possible to provide a muscular-force supplementing device with greater safety.

[0093] Fig. 5 shows a muscular-force supplementing device 50 according to a third embodiment. In this embodiment, as shown in Fig. 5(a), an elastic belt 44 is connected between connecting portions 8a1 and 8b1 of mounting portions 8a and 8b. At the allowable bending angle θ of a user, the elastic belt 44 inhibits, by its own tension, a joint from being bent at an angle greater than the allowable bending angle θ, as shown in Fig. 5(b). When using the elastic belt 44, the length thereof is adjusted in accordance with the allowable bending angle θ of the joint of the user.

[0094] Since this prevents the joint from bending excessively, in a manner similar to that in the second embodiment, it is possible to provide a muscular-force supplementing device with greater safety.

[0095] Fig. 6 shows a muscular-force supplementing

device 60 of a fourth embodiment. This device 60 comprises an artificial muscular-force generating section 62, and a control section 64 for controlling the driving of the artificial muscular-force generating section 62.

[0096] The artificial muscular-force generating section 62 comprises first and second mounting portions 66a and 66b worn at two positions on both sides of a wrist joint of the user, and a hydraulic actuator 68 detachably connected between the first and second mounting portions 66a and 66b.

[0097] Fig. 7 concretely shows the structure of the artificial muscular-force generating section 62. The first mounting portion 66a is provided with concave connecting portions 66a1 which are arranged at predetermined intervals in the circumferential direction on the side opposing the second mounting portion 66b. The second mounting portion 66b is also provided with concave connecting portions 66b1 which are arranged at predetermined intervals in the circumferential direction on the side opposing the first mounting portion 66a.

[0098] The actuator 68 is composed of a plurality of actuator divisions 70 placed in parallel, as shown in Fig. 7. Each of the actuator divisions 70 includes an elongated expandable portion 70a having a pressure chamber therein so as to expand in the longitudinal direction and to thereby generate a predetermined amount of actuator force, and connecting portions 70b and 70c fixed to both ends of the expandable portion 70a.

[0099] One of the connecting portions 70b is detachably fitted in the connecting portion 66a1 of the first mounting portion 66a, and the other connecting portion 70c is detachably fitted in the connecting portion 66b1 of the second mounting portion 66b, whereby a plurality of actuator divisions 70 are detachably connected between the first and second mounting portions 66a and 66b.

[0100] The other connecting portion 70c of each of the actuator divisions 70 has an oil path 70c1 communicating with the pressure chamber. One end of an oil path 66b2 formed inside the second mounting portion 66b is opened in the connecting portions 66b1 of the second mounting portion 66b. The oil path 66b2 is connected to a feed and feedback control section 74 of the control section 64, which will be described later. When the other connecting portions 70c of the actuator divisions 70 are detachably fitted in the connecting portions 66b1, the oil path 70c1 and the oil path 66b2 are caused to communicate with each other.

[0101] It is assumed that a connecting portion 66b1 of the second mounting portion 66b, to which no actuator division 70 is connected, is disconnected from the oil path 66b2 by a blocking means that is not shown.

[0102] When hydraulic oil is supplied from the control section 64 to the artificial muscular-force generating section 62, it flows into the pressure chambers in the actuator divisions 70 connected between the first and second mounting portions 66a and 66b, and the expandable portions 70a are thereby expanded. Then, substantially linear actuator force is transmitted to the mounting portions 66a and 66b, and bending force is transmitted to the joint of the user.

[0103] As shown in Fig. 9, the control section 64 comprises a reservoir 72 for storing hydraulic oil, a feed and feedback control section 74 for controlling feeding and feedback of hydraulic oil to and from the actuator divisions 70 constituting the artificial muscular-force generating section 62, a driving control device 76 for controlling the driving of the feed and feedback control section 74, a power supply section 78 for supplying external power to the feed and feedback control section 74, a hydraulic oil supply and discharge section 80 for supplying hydraulic oil to the reservoir 72 or discharging hydraulic oil in the reservoir 72, a cord reel 84 for winding up a power cord 82 extending from the power supply section 78, and a power cord alarm section 86 for sounding an alarm when the length of the power cord 82 remaining in the cord reel 84 is short.

[0104] The feed and feedback control section 74 is electrically driven and exerts control so as to feed hydraulic oil, which is received from the reservoir 72, to the actuator divisions 70 and to feed back hydraulic oil from the pressure chambers of the actuator divisions 70 to the reservoir 72.

[0105] The hydraulic oil supply and discharge section 80 includes a supply and discharge tube 80a connected to the reservoir 72 at one end, an on-off valve 80b interposed in the supply and discharge tube 80a, an oil filter 80c placed on an open-end side of the supply and discharge tube 80a, and a valve control section 80d for controlling opening and closing of the on-off valve 80b. A leakage detector 80e for detecting leakage of hydraulic oil is connected to a portion of the supply and discharge tube 80a between the on-off valve 80b and the oil filter 80c. An alarm device 80f is connected to the valve control section 80d. When the leakage detector 80e detects that hydraulic oil is leaking when the supply and discharge tube 80a is insulated from outside air by closing the on-off valve 80b under control of the valve control section 80d, the valve control section 80d outputs a signal to the alarm device 80f so that the alarm device 80f sounds an alarm. The supply and discharge tube 80a, the on-off valve 80b, the valve control section 80d, the leakage detector 80e, and the alarm device 80f correspond to the fluid discharge control section of the present invention. The supply and discharge tube 80a, the on-off valve 80b, the valve control section 80d, and the oil filter 80c correspond to the fluid supply control section of the present invention.

[0106] On the other hand, the cord reel 84 is worn on the body of the user via a holder 102 that will be described later (see Fig. 11). The user winds up the power cord 82 by a predetermined length. The power cord alarm section 86 monitors the state of the power cord 82 drawn from the cord reel 84.

[0107] As shown in Fig. 9, the power cord alarm section 86 is composed of a cord length detector 88, a cord

length determining section 90 for determining the length of the power cord 82 drawn from the cord reel 84 based on the detection result of the cord length detector 88, and an alarm device 92 for sounding an alarm in response to a signal output from the cord length determining section 90 when the length of the power cord 82 remaining in the cord reel 84 is short.

[0108] The cord length detector 88 may have a structure shown in Fig. 10 in which a plurality of slits 94a are formed on the outer peripheries of rotating disks 96 of a drum 94 built in the cord reel 84 and a light-emitting element 98 and a photodiode 100 are arranged opposed to the positions of the slits 94a. In this structure, light emitted from the light-emitting element 98 is received by the photodiode 100 via the slits 94a and the light traveling toward the photodiode 100 is blocked at the positions where no slits 94a are formed. The photodiode 100 outputs, to the cord length determining section 90, a signal when the drum 94 is rotated by a predetermined angle in order to draw the power cord 82. The cord length determining section 90 determines the length of the power cord 82 drawn from the drum 94 based on the signal obtained from the photodiode 100. While the cord reel 84 is worn on the body of the user via the holder 102, as shown in Fig. 11, the holder 102 has a gyro mechanism for rotating the entire cord reel 84 so that a cord-dispensing hole 84a of the cord reel 84 freely points upward and downward or rightward and leftward.

[0109] A manner of using the muscular-force supplementing device 60 with the above configuration will be briefly described below with reference to Figs. 6 to 11.

[0110] First, a predetermined amount of hydraulic oil is stored in the reservoir 72 through the supply and discharge tube 80a. In this case, since the oil filter 80c is interposed in the supply and discharge tube 80a, it removes impurities, such as dust, mixed in the hydraulic oil.

[0111] Subsequently, as shown in Fig. 7, a predetermined number of actuator divisions 70 are detachably connected to the connecting portions 66a1 and 66b1 of the first and second mounting portions 66a and 66b so as to generate actuator force in accordance with the power of muscular force that the user desires.

[0112] Then, the mounting portions 66a and 66b are put on the hand and arm sides of the user, as shown in Fig. 6.

[0113] Subsequently, the power cord 82 is drawn from the cord reel 84 by a required length, and a plug of the power cord 82 is put into a socket 104, as shown in Fig. 11, When the power cord 82 is thus drawn out of the cord reel 84 by the required length, it can be prevented from becoming entangled.

[0114] Then, the feed and feedback control section 74 is operated so as to generate supplementary muscular force in the artificial muscular-force generating section 62.

[0115] That is, the feed and feedback control section 74 increases the pressure of the hydraulic oil received from the reservoir 72 to a predetermined pressure and supplies the hydraulic oil to the pressure chambers of the actuator divisions 70. When the hydraulic oil is supplied to the pressure chambers, the actuator divisions 70 are expanded so as to apply linear actuator force to the first and second mounting portions 66a and 66b, as shown in Fig. 8, and bending force (supplementary muscular force) is transmitted to the joint of the user. After a predetermined time, the feed and feedback control section 74 returns the hydraulic oil in the pressure chambers of the actuator divisions 70 to the reservoir 72, thereby discontinuing transmission of the supplementary muscular force to the joint of the user.

[0116] The user wears the cord reel 84 on the body via the holder 102, as shown in Fig. 11. Since the gyro mechanism built in the holder 102 exerts control so that the cord-dispensing hole 84a of the cord reel 84 is constantly oriented in the extending direction of the power cord 82 (toward the socket 104), the power cord 82 can be smoothly drawn out of the cord reel 84.

[0117] In a case in which the length of the power cord 82 remaining in the cord reel 84 is short, the cord length determining section 90 of the power cord alarm section 86 outputs a signal to the alarm device 92 based on information about the length of the power cord 82 obtained from the cord length detector 88. The alarm device 92, to which the signal is input from the cord length determining section 90, sounds an alarm, whereby the user can ascertain that the length of the power cord 82 presently remaining in the cord reel 84 is short.

[0118] In a case in which hydraulic oil is leaking from the supply and discharge tube 80a, for example, due to failure of the on-off valve 80b while supplementary muscular force is being generated in the artificial muscular-force generating section 62, the valve control section 80d outputs a signal to the alarm device 80f based on a leakage information signal from the leakage detector 80e. The alarm device 80f, to which the signal is input from the valve control section 80d, sounds an alarm, and this allows the user to ascertain that the hydraulic oil is leaking from the supply and discharge tube 80a. When moving the muscular-force supplementing device 60, which is placed in a non-operation state, to another place, the hydraulic oil in the reservoir 72 is discharged to the outside through the supply and discharge tube 80a. The actuator divisions 70 detachably connected to the connecting portions 66a1 and 66b1 of the first and second mounting portions 66a and 66b are also detached. The weight of the entire control section 64, from which the hydraulic oil is discharged, is reduced, and the artificial muscular-force generating section 62, in which the first and second mounting portions 66a and 66b and the actuator divisions 70 are separated, is made compact.

[0119] Therefore, according to the muscular-force supplementing device 60 of this embodiment, since actuator force can be varied by merely varying the number of actuator divisions 70 detachably connected to the

connecting portions 66a1 and 66b1 of the first and second mounting portions 66a and 66b, it is possible to freely set the power of supplementary muscular force as the user desires.

[0120] The other connecting portions 70c of the actuator divisions 70 have the oil paths 70c1 communicating with the pressure chambers of the actuator divisions 70. When the other connecting portions 70c of the actuator divisions 70 are fitted, the oil paths 70c1 and the oil path 66b2 are caused to communicate with each other. Therefore, tubes for supplying hydraulic oil and the like are not exposed outside the device, and the artificial muscular-force generating section 62 can be handled easily.

[0121] When storing a predetermined amount of hydraulic oil in the reservoir 72, the oil filter 80c interposed in the supply and discharge tube 80a can remove impurities, such as dust, mixed in the hydraulic oil. For this reason, the feed and feedback control section 74 exerts control to feed and feed back hydraulic oil containing no impurities, which can substantially reduce problems due to impurities.

[0122] By discharging hydraulic oil in the reservoir 72 by using the supply and discharge tube 80a, the device is decreased in weight. By detaching the actuator divisions 70 detachably connected to the connecting portions 66a1 and 66b1 of the first and second mounting portions 66a and 66b, the artificial muscular-force generating section 62 can be made compact. This allows the muscular-force supplementing device 60 in a non-operation state to be easily moved to another place. Moreover, the storage space for the device can be reduced.

[0123] Since the alarm device 80f of the hydraulic oil supply and discharge section 80 sounds an alarm, it is possible to immediately inform the user that an abnormal condition exists in which hydraulic oil in the reservoir 72 is leaking to the outside.

[0124] Since the alarm device 92 of the power cord alarm section 86 sounds an alarm, it is possible to immediately inform the user that the length of the power cord 82 presently remaining in the cord reel 84 is short. This makes it possible to prevent the power cord 82 from being completely pulled out of the socket 104 because the power cord 82 is excessively drawn.

[0125] Fig. 12 shows a muscular-force supplementing device 110 according to a fifth embodiment. This device 110 comprises an artificial muscular-force generating section 112 and a control section 114 for controlling the driving of the artificial muscular-force generating section 112.

[0126] The artificial muscular-force generating section 112 is composed of a mounting portion 116, and an inner actuator 118A and an outer actuator 118B formed integrally with the outer periphery of the mounting portion 116. Herein, "inner" of the inner actuator 118A refers to the interior-angle side of a joint of a user when the device is worn thereat. In contrast, "outer" of the outer actuator 118B refers to the exterior-angle side of the joint of the user when the device is worn thereat.

[0127] The mounting portion 116 is a flexible member made of leather, a synthetic resin sheet, or the like, and is shaped like a cylinder so as to wrap the joint of the user in close contact therewith. The outer periphery of the mounting portion 116 is coated with a flexible coating material 117 made of a high polymer which is able to absorb liquid, as shown in Fig. 13.

[0128] The inner actuator 118A is operated by fluid pressure, and comprises a plurality of blocks 120a made of a hard material, which are arranged in the longitudinal direction of the mounting portion 116 with a predetermined space therebetween and are fixed on the coating material 117, and a plurality of elastic members 122a1 and 122a2 placed in the spaces between the blocks 120a. The elastic members 122a1 placed on the outer periphery of the mounting portion 116 have pressure chambers therein, are connected in series to one another via oil paths formed in the blocks 120a, and are connected to an oil path 130a1 extending to the control section 114 which will be described later. The elastic members 122a2 placed adjacent to the mounting portion 116 are also connected in series with one another via oil paths formed in the blocks 120a and are connected to an oil path 130a2 extending to the control section 114.

[0129] The space and height of the above-described blocks 120a are set so that the adjoining blocks 120a contact to stop application of supplementary muscular force before supplementary muscular force is excessively applied to the joint of the user.

[0130] The outer actuator 118B is also operated by fluid pressure, and comprises a plurality of blocks 120b arranged in the longitudinal direction of the mounting portion 116 with a predetermined space therebetween and fixed on the coating material 117, and a plurality of elastic members 122b1 and 122b2 placed in the spaces between the blocks 120b. The elastic members 122b1 placed on the outer periphery of the mounting portion 116 have pressure chambers therein, are connected in series to one another via oil paths formed in the blocks 120b, and are connected to an oil path 130b1 extending to the control section 114. The elastic members 122b2 placed adjacent to the mounting portion 116 are also connected in series with one another via oil paths formed in the blocks 120b and are connected to an oil path 130b2 extending to the control section 114.

[0131] As shown in Fig. 14, the control section 114 comprises a reservoir 124 for storing hydraulic oil to be used in the device, a heater 126 for heating the hydraulic oil in the reservoir 124 to a predetermined temperature, a plurality of hydraulic-oil feeders 128a and 128b for independently supplying the hydraulic oil in the reservoir 124 to the inner actuator 118A and the outer actuator 118B, a feeding-drive control device 132 for controlling the driving of the hydraulic-oil feeders 128a and 128b, a power supply section 134 for supplying power to the hydraulic-oil feeders 128a and 128b, and a generated-

force stabilizing section 136 for preventing generated actuator force from being suddenly decreased even when trouble occurs in a portion of the inner and outer actuators 118A and 118B.

[0132] After supplying hydraulic oil from the reservoir 124 to the inner actuator 118A and the outer actuator 118B, the hydraulic-oil feeder 128a exchanges hydraulic oil between the pressure chambers of the elastic members 122a1 of the inner actuator 118A and the pressure chambers of the elastic members 122b1 of the outer actuator 118B via the oil paths 130a1 and 130b1. The hydraulic-oil feeder 128b exchanges hydraulic oil between the pressure chambers of the elastic members 122a2 of the inner actuator 118A and the pressure chambers of the elastic members 122b2 of the outer actuator 118B via the oil paths 130a2 and 130b2.

[0133] The feeding-drive control device 132 controls the operations of the hydraulic-oil feeders 128a and 128b. Information about the muscular force of the user is input from a muscular-force detector 138 to the device 132.

[0134] The muscular-force detector 138 comprises, as shown in Fig. 16, a driving motor 138a placed in a through hole extending toward the inner peripheral surface of the mounting portion 116 so that its rotation shaft points inward, a gear 138b fixed to the rotation shaft of the driving motor 138a, a rack 138c meshed with the gear 138b, a pushrod 138d formed integrally with the rack 138c and movably placed in the mounting portion 116, and a torque measuring instrument 138e placed at the top of the driving motor 138a. Rotational motion of the driving motor 138a is converted into linear motion of the pushrod 138d via the gear 138b and the rack 138c, and pressing force is applied from the pushrod 138d to the skin of the user. Since the torque of the driving motor 138a is changed by the pressing force, the torque value is detected by the torque measuring instrument 138e and is output to the feeding-drive control device 132.

[0135] Referring again to Fig. 14, the generated-force stabilizing section 136 comprises a plurality of pressure sensors 136a1, 136a2, 136a3, and 136a4 for detecting the pressures in the oil paths 130a1, 130b1, 130a2, and 130b2, control valves 136b1, 136b2, 136b3, 136b4 interposed in the oil paths 130a1, 130b1, 130a2, and 130b2, and a generated-force generation control section 136d for obtaining pressure information from the pressure sensors 136a1, 136a2, 136a3, and 136a4, and closing a control valve corresponding to a pressure chamber of a given elastic member where the pressure is lower than the standard pressure (for example, the control valve 136b1 in the case of the pressure chamber of the elastic member 122a1).

[0136] A manner of using the muscular-force supplementing device 110 with the above-described configuration will be briefly described with reference to Figs. 12 to 15.

[0137] First, the mounting portion 116 is put on the arm of the user, as shown in Fig. 12. Subsequently, the muscular-force detector 138 is activated so as to measure the hardness of muscles of the user while temporarily pressing the pushrod 138d against the skin of the user. Muscle information obtained based on the measured value is output to the feeding-drive control device 132. The feeding-drive control device 132 starts operation of the hydraulic-oil feeders 128a and 128b based on the obtained information about the muscle of the user.

[0138] The hydraulic-oil feeders 128a and 128b receive heated hydraulic oil from the reservoir 124 and exchange hydraulic oil between the inner actuator 118A and the outer actuator 118B.

[0139] In order to transmit bending force (supplementary muscular force) to the joint of the user, control is exerted so as to transfer hydraulic oil in the pressure chambers of the elastic members 122a1 and 122a2 of the inner actuator 118A to the pressure chambers of the elastic members 122b1 and 122b2 of the outer actuator 118B. When the hydraulic oil is transferred into the pressure chambers of the elastic members 122b1 and 122b2 of the outer actuator 118B, the blocks 120b are pressed by the expanded elastic members 122b1 and 122b2, whereby actuator force is generated so as to apply bending force to the mounting portion 116, and supplementary muscular force for bending is transmitted to the joint of the user.

[0140] In order to transmit straightening force (supplementary muscular force) to the joint of the user, control is exerted so that hydraulic oil in the pressure chambers of the elastic members 122b1 and 122b2 of the outer actuator 118B is transferred to the pressure chambers in the elastic members 122a 1 and 122a2 of the inner actuator 118A. When the hydraulic oil is transferred into the pressure chambers of the elastic members 112a1 and 122a2 of the inner actuator 118A, the blocks 120a are pressed by the expanded elastic members 122a1 and 122a2, whereby actuator force is generated so as to apply straightening force to the mounting portion 116, and supplementary muscular force for straightening is transmitted to the joint of the user.

[0141] If trouble, such as oil leakage, occurs in a portion of the inner and outer actuators 118A and 118B, for example, when the pressure sensor 136a1 measures a low value, the generated-force generation control section 136d of the generated-force stabilizing section 136 outputs a signal for a closing operation to the control valve 136b1. This prevents all the actuators from being disenabled due to leakage of the hydraulic oil. Actuator force is thus generated by transferring the hydraulic oil among the pressure chambers in the elastic members 122a1 and 122a2 of the inner actuator 118A, the pressure chambers in the elastic members 122b1 and 122b2, and the reservoir 124.

[0142] The advantages of the muscular-force supplementing device 110 of this embodiment will now be described.

[0143] Since hydraulic oil in the reservoir 124, which is heated by the heater 126, is supplied to the inner ac-

tuator 118A and the outer actuator 118B, the mounting portion 116, to which heat is conducted from the hydraulic oil, does not become cold. Therefore, the user can comfortably wear the device in winter.

[0144] In the device 110, there are no actuators (artificial rubber muscles) which are not in close contact with the body, for example, as in the second conventional art, and the inner actuator 118A and the outer actuator 118B are simply placed along the outer periphery of the mounting portion 116. This makes it possible to provide an easily wearable device.

[0145] Even when the inner actuator 118A and the outer actuator 118B are partly faulty, the generated-force stabilizing section 136 separates the pressure chamber where oil leakage occurs, thereby preventing both the actuators from being disenabled due to leakage of the hydraulic oil. Therefore, in a case in which the actuator breaks when the user is carrying something heavy, it is possible to prevent the joint from being damaged due to a sudden loss of supplementary muscular force.

[0146] Since the inner periphery of the inner actuator 118A and the outer actuator 118B is coated with the coating material 117 made of a high polymer capable of absorbing liquid, even if hydraulic oil leaks from the inner actuator 118A and the outer actuator 118B, the coating material 117 can absorb the oil. and no oil will leak to the outside. Furthermore, though not shown, the outer periphery of the inner actuator 118A and the outer actuator 118B is coated with the coating material 117 made of a high polymer to effectively absorb leaked oil, thereby preventing the leakage to the outside of the muscular-force supplementing device.

[0147] Since the muscular-force detector 138 is operated to obtain information about the muscle of the user by temporarily pressing the pushrod 138d against the skin of the user, problems, such as inflammation of the skin as in the first conventional art utilizing a myoelectric sensor, will not arise. Furthermore, the hydraulic-oil feeders 128a and 128b transfer hydraulic oil between the inner actuator 118A and the outer actuator 118B. The pressure chambers of the outer actuator 118B also serve as reservoirs when putting hydraulic oil into the pressure chambers of the inner actuator 118A, and the pressure chambers of the inner actuator 118A also serve as reservoirs when putting hydraulic oil into the pressure chambers of the outer actuator 118B. Therefore, no reservoir is necessary, or only a reservoir having a small capacity is necessary so as to compensate for leakage of a small amount of hydraulic oil. This reduces the amount of hydraulic oil and allows a smaller and lighter device.

[0148] When transmitting supplementary muscular force for bending to the joint of the user, the adjoining blocks 120a of a plurality of blocks 120a in the inner actuator 118A contact so as to stop application of supplementary muscular force before the supplementary muscular force is excessively applied to the joint of the user. Therefore, it is possible to provide a muscular-force supplementing device with greater safety.

[0149] Fig. 17 shows a muscular-force supplementing device 140 according to a sixth embodiment, in which an actuator has a structure different from that in the fifth embodiment. The same components as those in the fifth embodiment are denoted by the same numerals, and descriptions thereof are omitted.

[0150] In the muscular-force supplementing device 140 of this embodiment, an outer actuator 142 is formed integrally with the outer periphery of a mounting portion 116.

[0151] The outer actuator 142 is driven by fluid pressure and comprises a plurality of blocks 144 made of a hard material and fixedly arranged in the longitudinal direction of the mounting portion 116 at predetermined intervals, and a plurality of elastic members 146 placed in the spaces between the blocks 144.

[0152] The elastic members 146 have respective pressure chambers therein, are connected in series to one another via oil paths formed in the blocks 144, and are connected to an oil path 148 extending to a control section 114.

[0153] When hydraulic oil flows into the pressure chambers of the elastic members 146, the elastic members 146 are expanded in the longitudinal direction so as to pressure the blocks 144 and to apply bending force to the mounting portion 116. Supplementary muscular force for bending is thereby transmitted to the joint of the user. When hydraulic oil flows out of the pressure chambers of the elastic members 146, the elastic members 146 are contracted so as to remove the bending force applied to the mounting portion 116.

[0154] By forming the outer actuator 142 with the above structure integrally with the outer periphery of the mounting portion 116, it is possible to provide an easily wearable device having no actuator (artificial rubber muscle) which is not in close contact with the body, for example, as in the second conventional art.

[0155] When generating supplementary muscular force, the pressure chambers of the outer actuator 142 are pressed and hardened with some capacity. In this embodiment, since the actuator is placed outside, it does not hinder bending of the arm of the user and does not reduce the range of movement of the arm.

[0156] While the devices of the above-described embodiments apply supplementary muscular force to the wrist joint of the user, even when the present invention is applied to devices for applying supplementary muscular force to various joints of the body, such as an arm joint and a knee joint, similar functions and advantages can be obtained.

[0157] While hydraulic cylinders are used as the actuators in the embodiments, they may be replaced with pneumatic cylinders.

[0158] Furthermore, the number of the hydraulic-oil feeders 24a, 24b, and 24c in the first embodiment and the number of the actuator divisions 70 in the fourth em-

bodiment are not limited to those mentioned in the embodiments.

Industrial Applicability

[0159] As described above, in the wearable muscular-force supplementing device of the present invention, the control means includes the artificial muscular-force releasing means for releasing the joint by stopping generation of supplementary muscular force in the artificial muscular-force generating means. When the user assumes a dangerous attitude, for example, when the user is going to fall down, generation of supplementary muscular force in the artificial muscular-force generating means is stopped, and the user can freely move the body without any restraint by the artificial muscular-force generating means. Since the control means includes the generated-force stabilizing means for restraining the force generated by the artificial muscular-force generating means from being reduced due to breakage, even when the actuator breaks while the user is carrying something heavy, the generated-force stabilizing means prevents the force generated by the actuator from being suddenly reduced.

[0160] The artificial muscular-force generating means is electrically driven, there are provided two power sources, a main power source and an auxiliary power source, and the main power source and the auxiliary power source are connected to the power switching device. The power switching device performs switching so as to supply power from the auxiliary power source for a predetermined period when the power supply from the main power source is stopped. Since power is supplied from the auxiliary power source when the supply from the main power source is stopped, it is possible to avoid the danger of a sudden loss of supplementary muscular force.

[0161] The artificial muscular-force generating means includes a pair of mounting portions to be worn at two positions on the body on both sides of the joint of the user, and an actuator connected between the mounting portions, wherein the actuator has the restraint means for preventing excessive supplementary muscular force from being applied to the joint of the user. This prevents the joint from being damaged due to excessive supplementary muscular force.

[0162] The artificial muscular-force generating means includes a fluid-pressure type actuator for applying supplementary muscular force to the joint, and the heater is provided so as to heat fluid serving as a working fluid for the actuator to a predetermined temperature. This prevents the user from feeling uncomfortable, for example, feeling cold when wearing the device.

Claims

1. A wearable muscular-force supplementing device comprising:

    artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user; and
    control means for controlling the driving of said artificial muscular-force generating means,
    wherein said control means has artificial muscular-force releasing means for releasing the joint from restraint by stopping generation of supplementary muscular force by said artificial muscular-force generating means.

2. A wearable muscular-force supplementing device according to Claim 1, wherein said artificial muscular-force releasing means has sensor means for detecting the attitude of the user, and release control means for stopping generation of supplementary muscular force by said artificial muscular-force generating means when determining, based on information detected by said sensor means, that the user is in a dangerous attitude, for example, that the user is going to fall down.

3. A wearable muscular-force supplementing device according to Claim 1 or 2, wherein said control means has voice input means and controls generation of supplementary muscular force to be applied to the joint by said artificial muscular-force generating means or exerts control so as to operate said artificial muscular-force releasing means, based on voice input from said voice input means.

4. A wearable muscular-force supplementing device according to Claim 2, wherein said artificial muscular-force generating means has a fluid-pressure type actuator, said control means includes a reservoir for storing fluid, a fluid feeding device for pressurizing and transferring the fluid received from said reservoir to said actuator, and a feeding-drive control device for controlling said fluid feeding device, said artificial muscular-force releasing means has a control valve interposed in a fluid path communicating with said actuator and connected to said reservoir while detouring around said fluid feeding device, and said release control means has an opening control section for controlling the opening of said control valve.

5. A wearable muscular-force supplementing device comprising:

    artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user; and
    control means for controlling the driving of said artificial muscular-force generating means,
    wherein said control means has generated-

force stabilizing means for inhibiting force generated by said artificial muscular-force generating means from being reduced due to breakage.

6. A wearable muscular-force supplementing device according to Claim 5, wherein said artificial muscular-force generating means includes a fluid-pressure type actuator having a plurality of pressure chambers, and said generated-force stabilizing means separates said pressure chambers.

7. A wearable muscular-force supplementing device according to Claim 6, wherein said control means includes a reservoir for storing fluid, a fluid feeding device for pressurizing and transferring the fluid received from said reservoir to said actuator, and a feeding-drive control device for controlling said fluid feeding device, and said generated-force stabilizing means includes a pressure sensor for detecting the pressures in said pressure chambers, control valves interposed in a plurality of flow paths connected between said fluid feeding device and said pressure chambers of said actuator, and a generated-force stabilization control section for closing a control valve connected to a given pressure chamber when it is determined based on information detected by said pressure sensor that the pressure in said pressure chamber is decreased.

8. A wearable muscular-force supplementing device comprising:

artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user; and
control means for controlling the driving of said artificial muscular-force generating means,
wherein said artificial muscular-force generating means is electrically driven, there are two power sources, a main power source and an auxiliary power source, said main power source and said auxiliary power source are connected to a power switching device, and said power switching device performs switching so as to supply power from said auxiliary power source for a predetermined time when power supply from said main power source is stopped.

9. A wearable muscular-force supplementing device according to Claim 8, wherein said power switching device has an alarm device for sounding an alarm when power supply from said auxiliary power source is started.

10. A wearable muscular-force supplementing device comprising:

artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user; and
control means for controlling the driving of said artificial muscular-force generating means,
wherein said artificial muscular-force generating means has a pair of mounting portions to be worn at two positions on the body of the user on both sides of the joint, and an actuator connected between said mounting portions, and said actuator has restraint means for preventing excessive supplementary muscular force from being applied to the joint of the user.

11. A wearable muscular-force supplementing device according to Claim 10, wherein said restraint means is formed by placing stopper members opposed to each other in said mounting portions so that the positions thereof are adjustable and so that said stopper members contact before excessive supplementary muscular force is applied to the joint of the user.

12. A wearable muscular-force supplementing device according to Claim 10, wherein said restraint means is formed by connecting a variable-length elastic belt between said mounting portions so that the force of said actuator is stopped by tension generated by said elastic belt before excessive supplementary muscular force is applied to the joint of the user.

13. A wearable muscular-force supplementing device comprising:

artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user; and
control means for controlling the driving of said artificial muscular-force generating means,
wherein said artificial muscular-force generating means has a pair of mounting portions to be worn at two positions on the body of the user on both sides of the joint, and an actuator connected between said mounting portions, said actuator is composed of a plurality of actuator divisions arranged in parallel and connected to one another between said mounting portions, said mounting portions have connecting portions for detachably connecting said actuator divisions thereto, and a predetermined number of said actuator divisions are detachably connected to said connecting portions of said mounting portions in accordance with a desired power of supplementary muscular force.

14. A wearable muscular-force supplementing device according to Claim 13, wherein said actuator divisions are formed of fluid-pressure type actuators

each having a pressure chamber therein, and said connecting portions of said mounting portions also serve as fluid transfer connectors for transferring fluid serving as working fluid into and out of said pressure chambers of said actuator divisions.

15. A wearable muscular-force supplementing device comprising:

artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user; and
control means for controlling the driving of said artificial muscular-force generating means,
wherein said artificial muscular-force generating means has a fluid-pressure type actuator having a pressure chamber, said control means includes a fluid transfer control section for controlling transfer of the fluid with respect to said actuator, and at least one of said actuator and said fluid transfer control section has a fluid discharge control section for discharging internal fluid to the outside.

16. A wearable muscular-force supplementing device according to Claim 15, wherein said fluid discharge control section has leakage alarm means for detecting leakage of the fluid and sounding an alarm when discharge of the fluid out of at least said actuator and said fluid transfer control section is stopped.

17. A wearable muscular-force supplementing device according to Claim 15 or 16, wherein said control means includes a fluid supply control section capable of supplying the fluid from the outside to at least one of said actuator and said fluid transfer control section, and filter means placed at an inlet of said fluid supply control section so as to remove foreign matters mixed in the fluid.

18. A wearable muscular-force supplementing device comprising:

artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user; and
control means for controlling the driving of said artificial muscular-force generating means,
wherein said control means is driven by power from an external power source, and has a power cord to be connected to said external power source, and a cord reel for winding up said power cord thereon.

19. A wearable muscular-force supplementing device according to Claim 18, wherein said cord reel is worn on the body of the user via a holder, and said holder has a mechanism for allowing a cord-dispensing hole of said cord reel to freely point upward, downward, rightward, and leftward.

20. A wearable muscular-force supplementing device according to Claim 19, wherein said control means has power cord alarm means for sounding an alarm when it is determined that the length of said power cord remaining in said cord reel is short.

21. A wearable muscular-force supplementing device comprising:

artificial muscular-force generating means for applying supplementary muscular force for bending to a joint of a user; and
control means for controlling the driving of said artificial muscular-force generating means,
wherein said artificial muscular-force generating means has a flexible mounting portion shaped like a cylinder so as to wrap the joint of the user in contact therewith, and a fluid-pressure type actuator formed integrally with the outer periphery of said mounting portion so as to apply supplementary muscular force to the joint while bending said mounting portion.

22. A wearable muscular-force supplementing device according to Claim 21, wherein said control means has a heating device for heating fluid serving as working fluid for said actuator to a predetermined temperature.

23. A wearable muscular-force supplementing device according to Claim 21 or 22, wherein said mounting portion is provided with muscular force detecting means for measuring muscular force based on pressing force temporarily applied to the skin of the user, and said control means controls supplementary muscular force generated by said actuator based on muscular force information obtained from said muscular force detecting means.

24. A wearable muscular-force supplementing device according to Claim 23, wherein said muscular force detecting means includes a driving motor, a transmission mechanism for transmitting rotating force of said driving motor as linear motion to a pushrod, and a torque measuring instrument for measuring the torque value of said driving motor when the skin is pushed by said pushrod and outputting the torque value as the pressing force to said control means.

25. A wearable muscular-force supplementing device according to any one of Claims 21 to 24, wherein said actuator is composed of an inner actuator placed on the inner side of the joint, extending in the longitudinal direction of the outer periphery of said mounting portion, and having a pressure

chamber made of an elastic material, and an outer actuator placed on the outer side of the joint, extending in the longitudinal direction of the outer periphery of said mounting portion, and having a pressure chamber made of an elastic material.

26. A wearable muscular-force supplementing device according to Claim 25, wherein said inner and outer actuators each have a plurality of convex members fixed on the outer periphery of said mounting portion with a predetermined space therebetween in the longitudinal direction, and a plurality of elastic members placed in the spaces between said convex members, each of said elastic members is expanded and contracted in response to the inflow and outflow of fluid into and from a pressure chamber formed therein, and each of said convex members is pressed by expansion of said elastic member so as to apply bending force to said mounting portion.

27. A wearable muscular-force supplementing device according to Claim 25 or 26, wherein said control means exerts control so as to transfer fluid between said pressure chambers of said elastic members constituting said inner actuator and said pressure chambers of said elastic members constituting said outer actuator.

28. A wearable muscular-force supplementing device according to any one of Claims 21 to 24, wherein said actuator is composed of an outer actuator placed on the outer side of the joint, extending in the longitudinal direction of the outer periphery of said mounting portion, and having a pressure chamber made of an elastic material, and the outer actuator is expanded in the longitudinal direction in response to the inflow of the fluid into said pressure chamber so as to apply bending force to said mounting portion, and is contracted in response to the outflow of the fluid from said pressure chamber so as to release the bending force on said mounting portion.

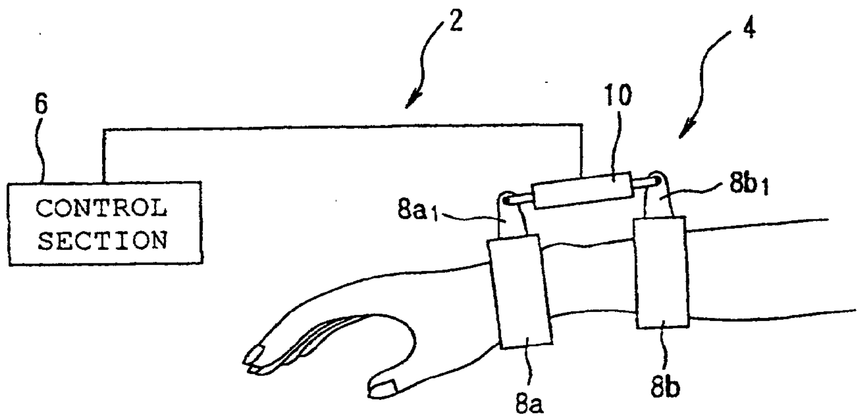
29. A wearable muscular-force supplementing device according to Claim 28, wherein said outer actuator includes a plurality of convex members fixed on the outer periphery of said mounting portion with a predetermined space therebetween in the longitudinal direction, and a plurality of elastic members placed in the spaces between said convex members, said elastic members are expanded in the longitudinal direction in response to the inflow of the fluid in a pressure chamber formed therein so as to press said convex members and to apply bending force to said mounting portion.

30. A wearable muscular-force supplementing device according to any one of Claims 21 to 29, wherein said control means has generated-force stabilizing means for inhibiting the force generated by said artificial muscular-force generating means from being reduced due to breakage.

31. A wearable muscular-force supplementing device according to Claim 26, 27, or 29, wherein said convex members function as stopper members for stopping application of supplementary muscular force by contacting with one another before excessive supplementary muscular force is applied to the joint of the user.

32. A wearable muscular-force supplementing device according to any one of Claims 21 to 31, wherein said fluid is liquid, and the outer or the inner periphery of the actuator integrated with said mounting portion is coated with a periphery-coating member having a liquid absorbing function.

FIG. 1


2
4
6
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CONTROL SECTION
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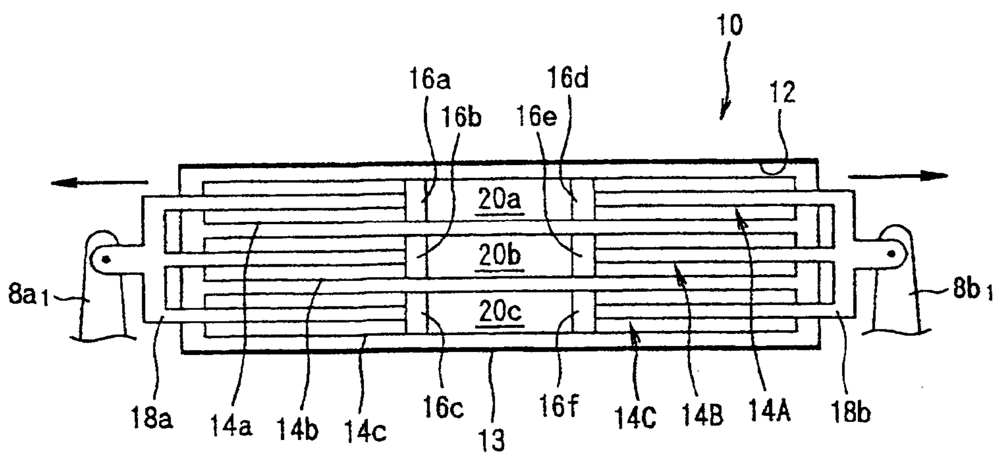
8b

FIG. 2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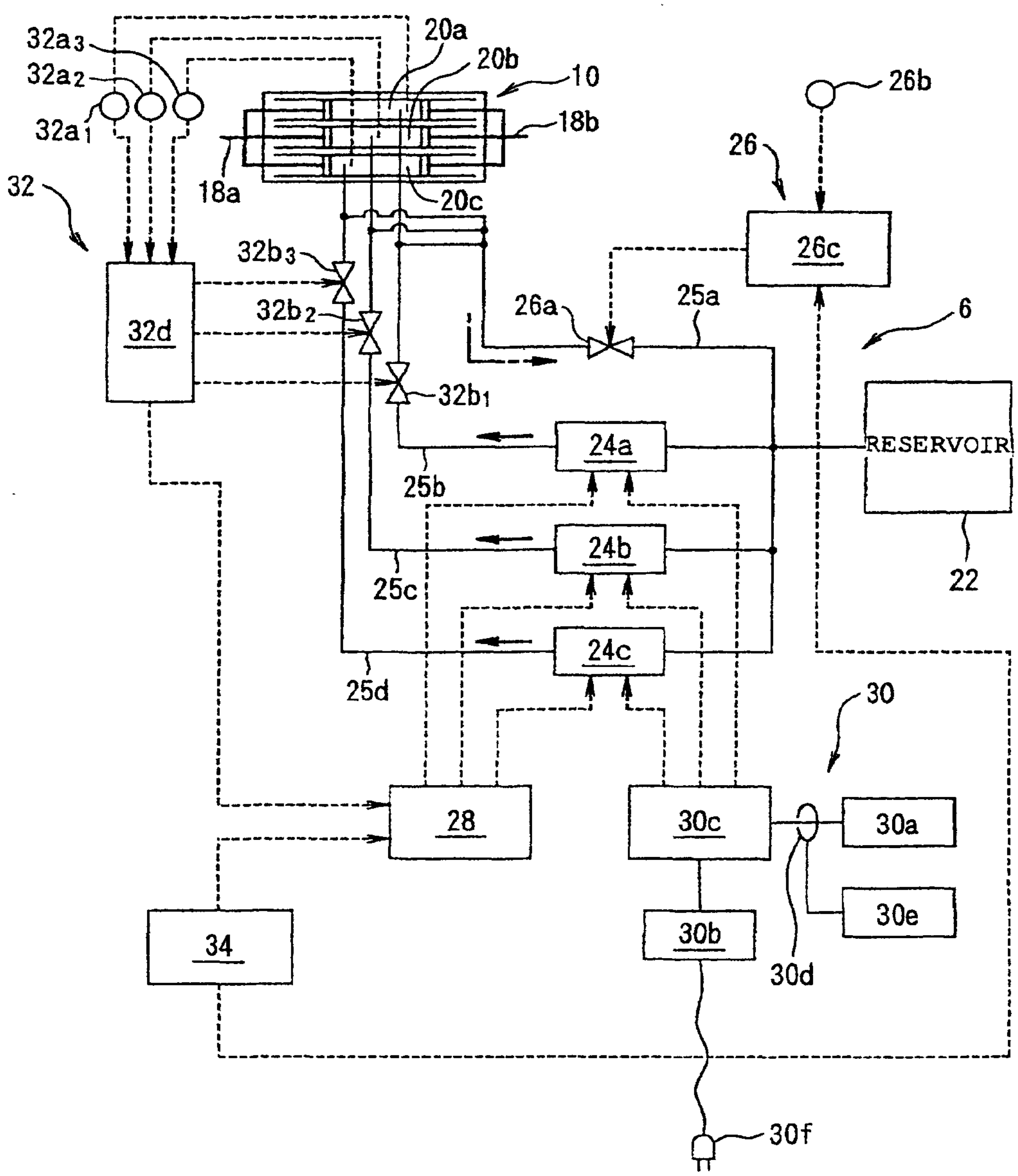
14C
14B
14A
18b

FIG. 3



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32a1
20a
20b
10
18b
18a
20c
26b
26
26c
32
32b3
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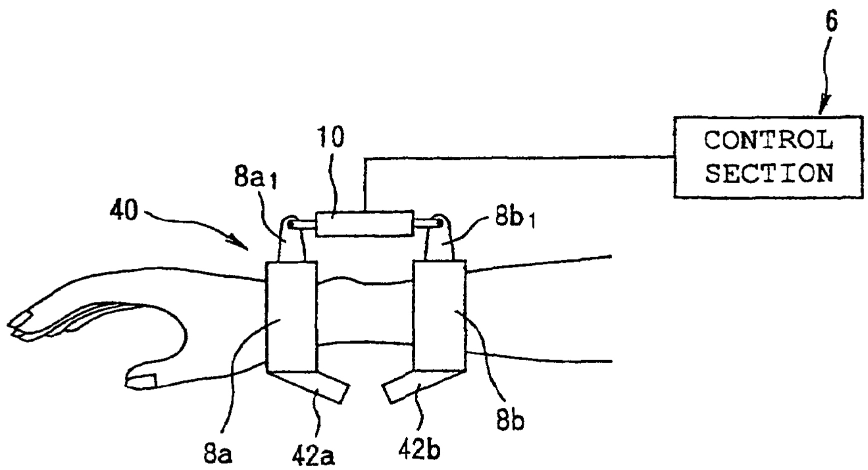
26a
25a
6
32b1
24a
RESERVOIR
25b
24b
22
25c
24c
25d
30
28
30c
30a
34
30b
30e
30d
30f

FIG. 4

(a)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SECTION
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$8b_1$
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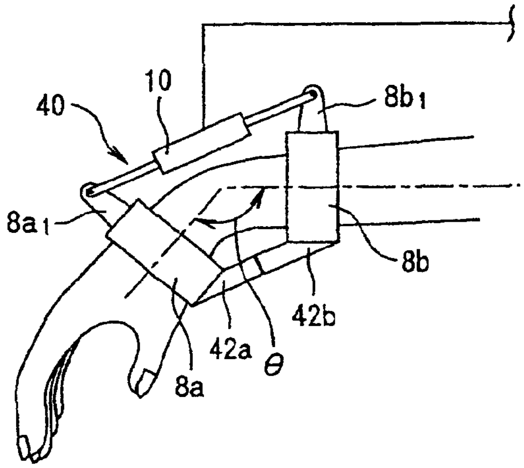
8a
42a
42b
8b

(b)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40
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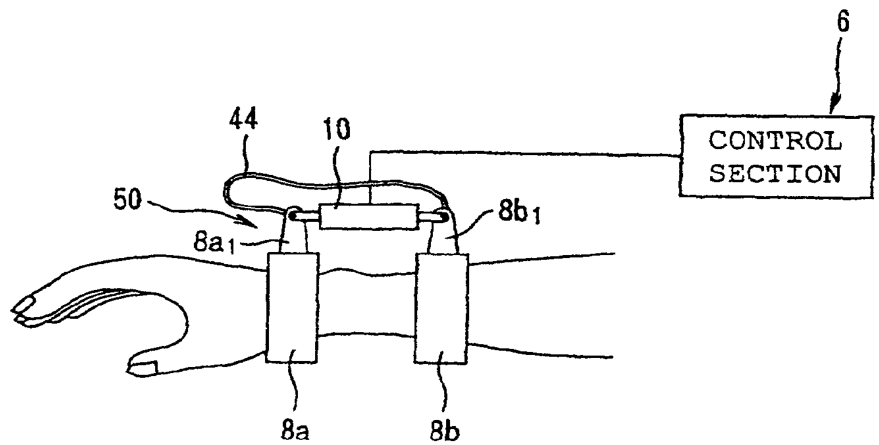
42a
θ
8a

FIG. 5

(a)



(b)

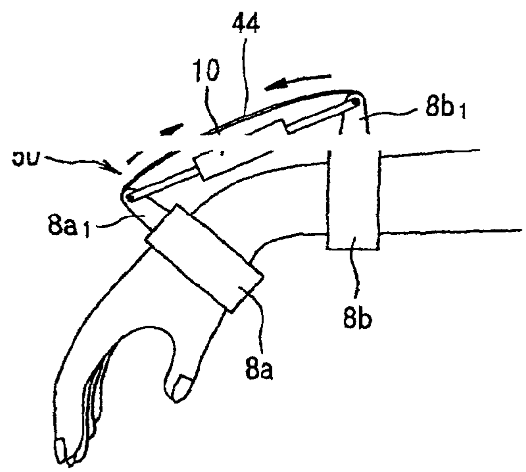
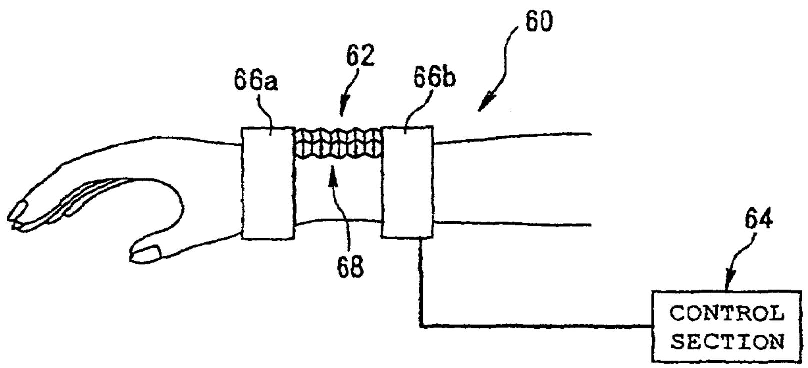


FIG. 6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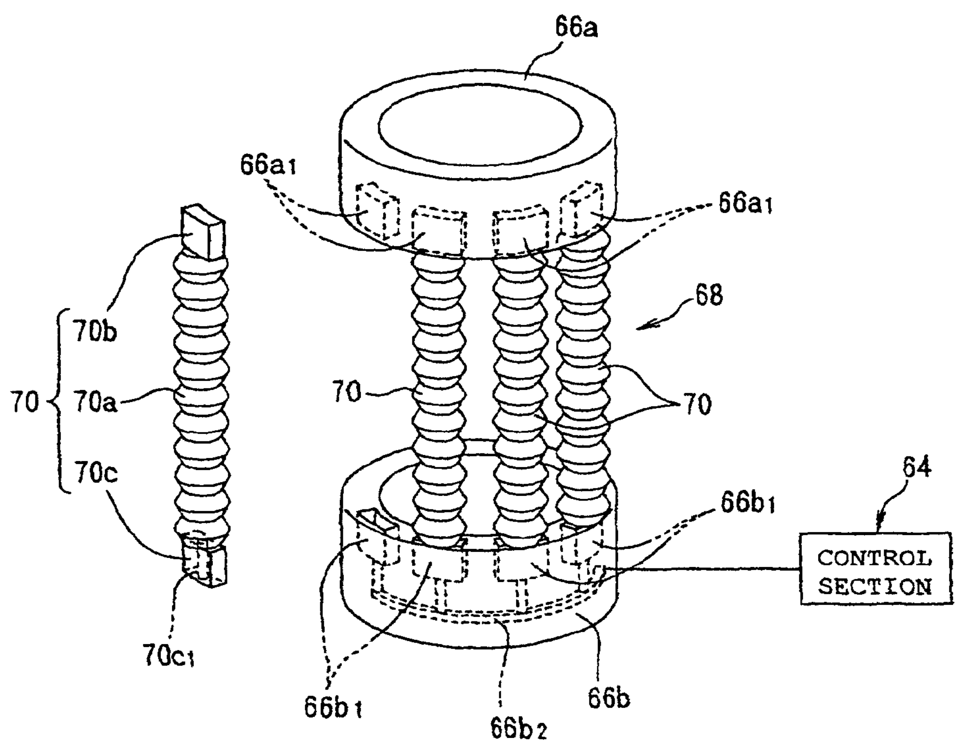
62
66a
66b
68
64
CONTROL SECTION

FIG. 7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64
66b1
CONTROL SECTION
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66b2
66b

FIG. 8

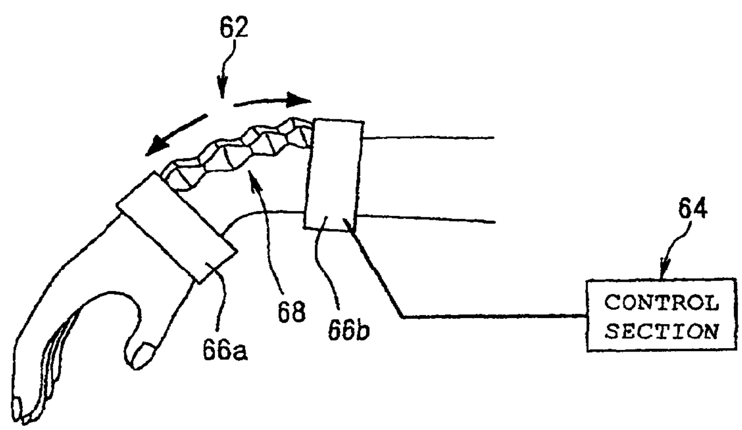
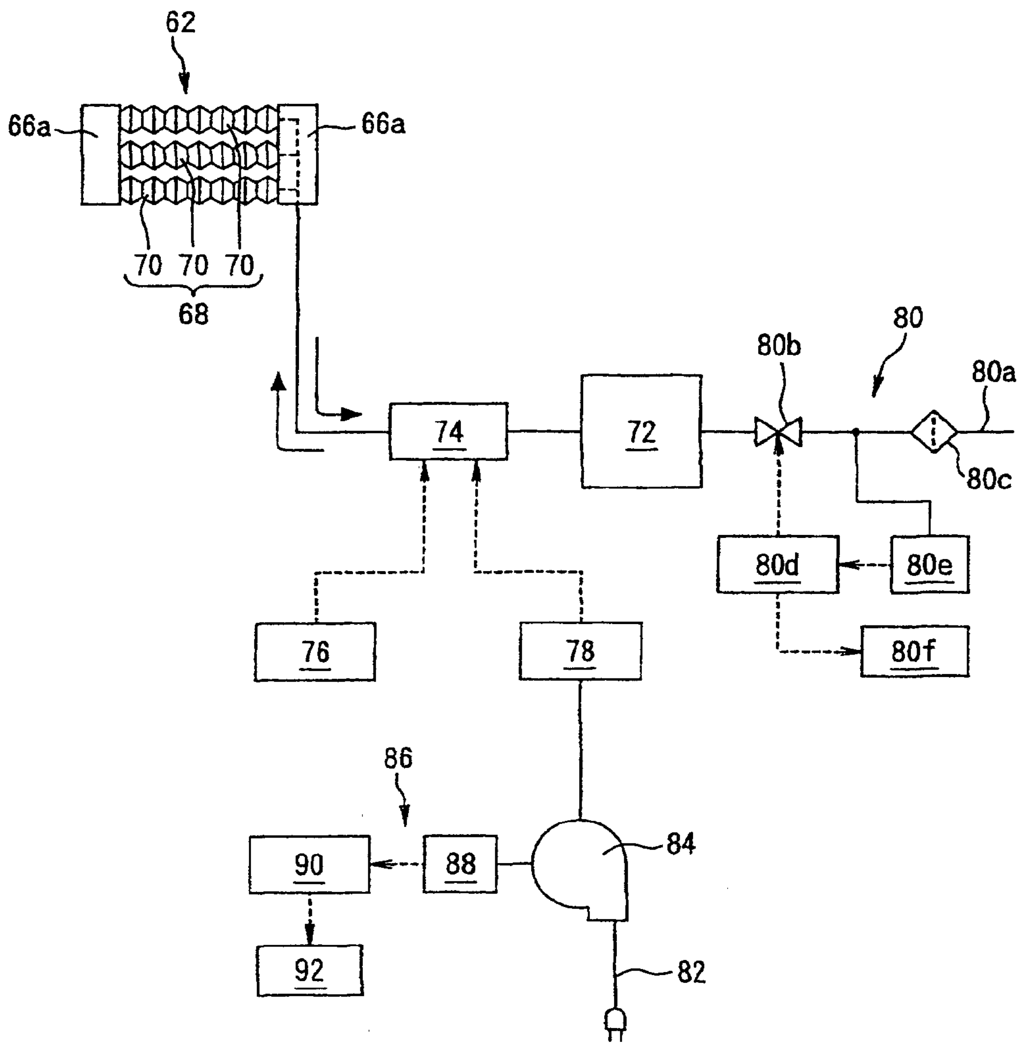


FIG. 9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66a
66a
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68
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80b
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88
92
82

FIG. 10

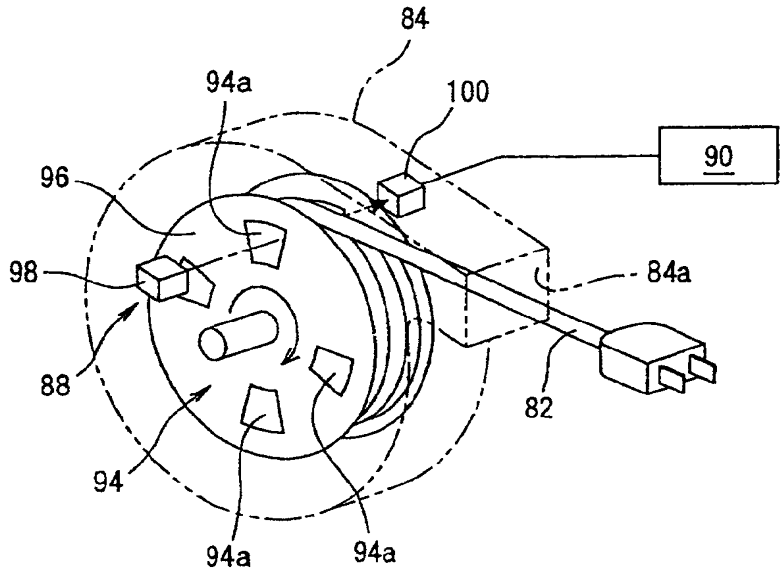


FIG. 11

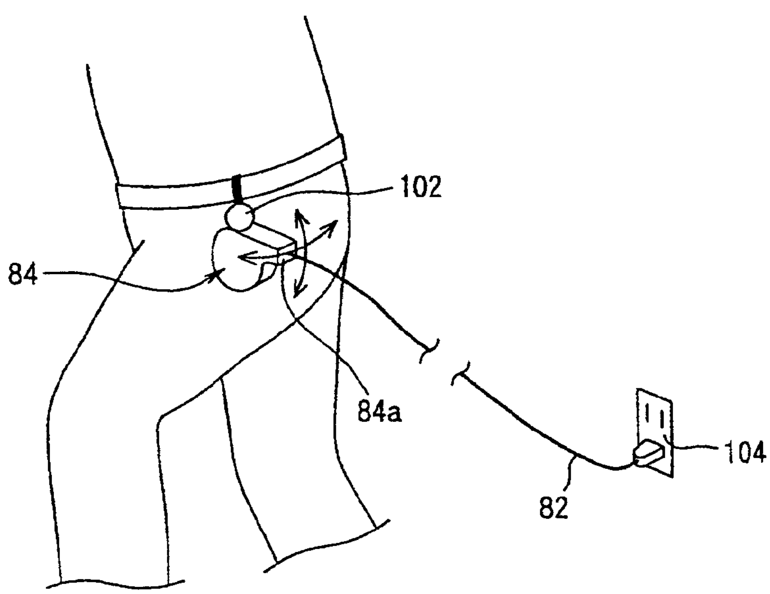


FIG. 12

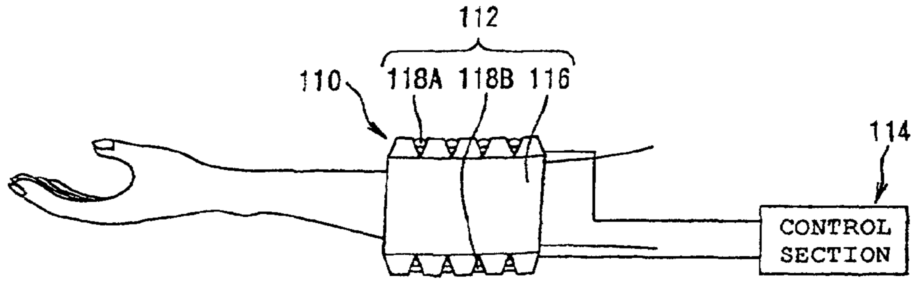
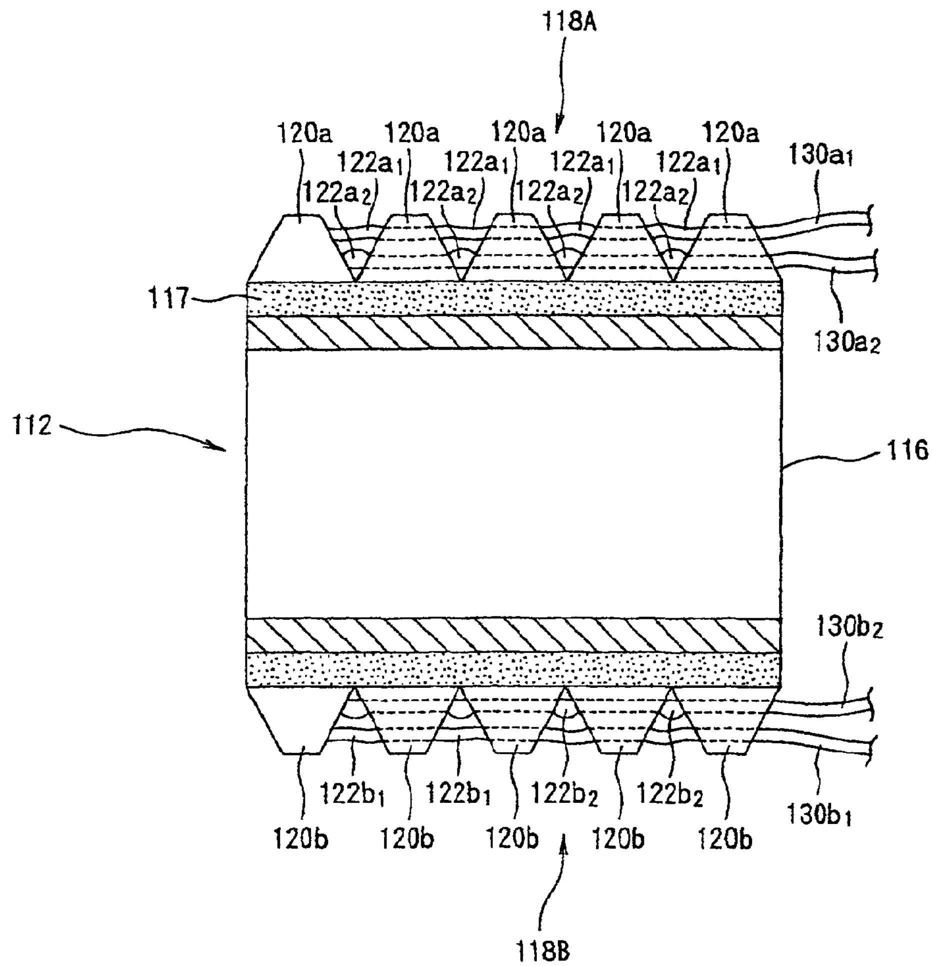

112
110
118A
118B
116
114
CONTROL
SECTION

FIG. 13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130a1
117
130a2
112
116
130b2
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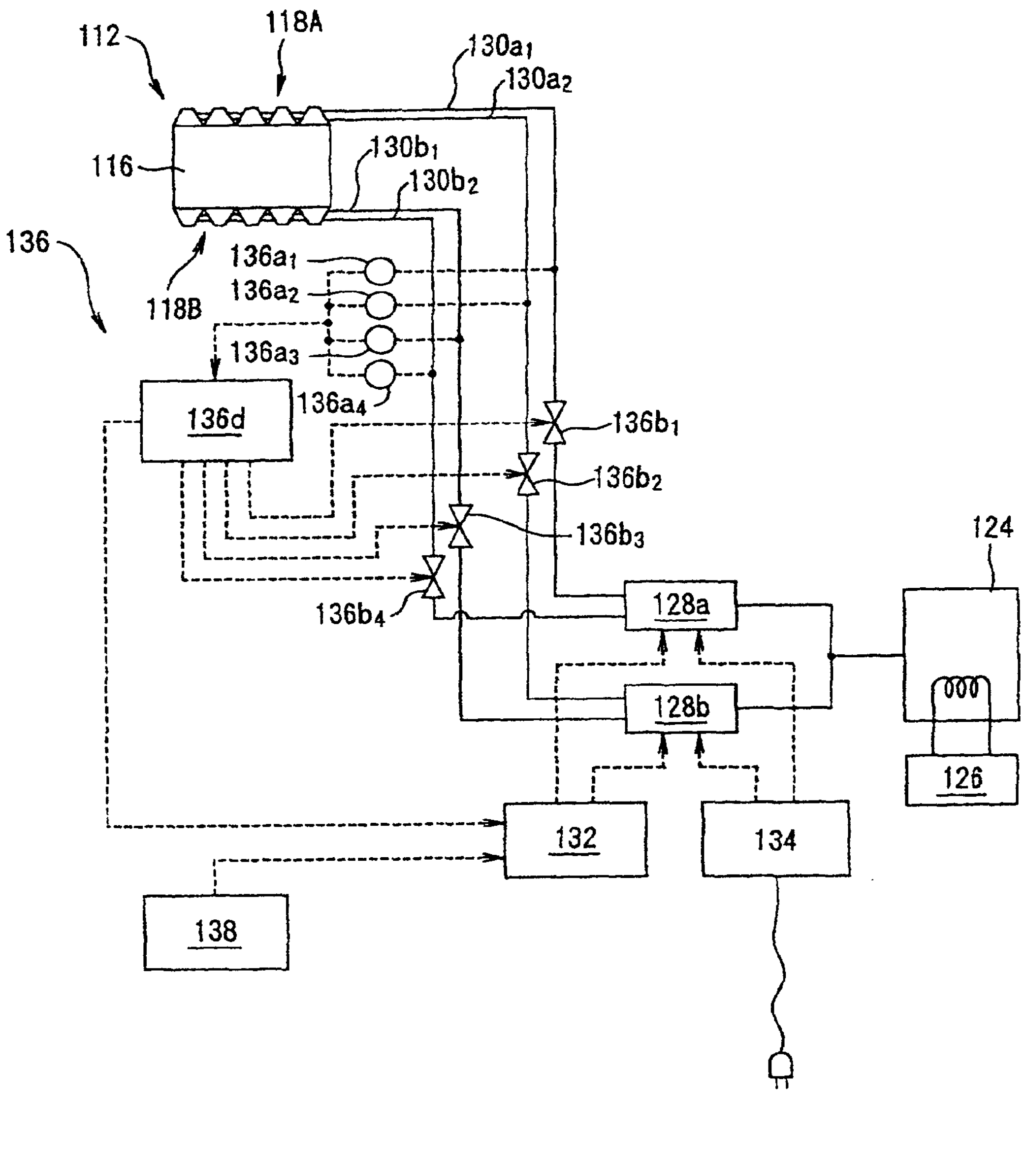
122b2
122b2
130b1
120b
120b
120b
120b
120b
118B

FIG. 14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132
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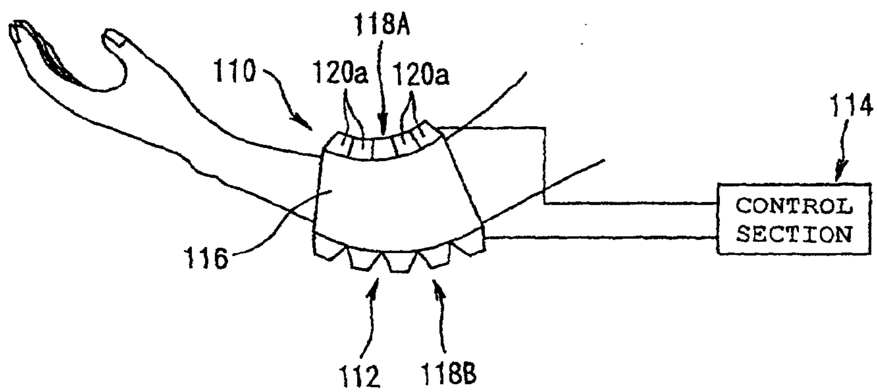
138

FIG. 15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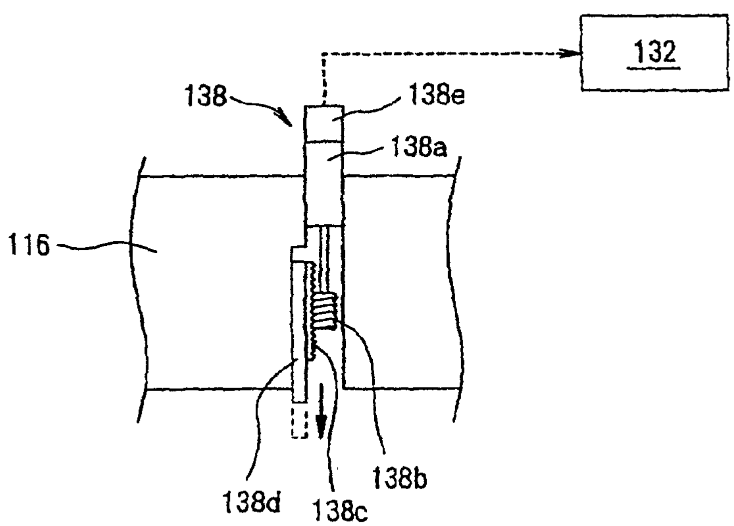
CONTROL SECTION
116
112
118B

FIG. 16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138
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138b

FIG. 17